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Status of the CDF Run II Silicon Detector

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Abstract

A snapshot of the status of the CDF Run II Silicon Detector is presented, with a summary of commissioning issues since the start of Run II, current performance of the detector, and the use of the data in both the trigger and offline reconstruction.

Key words: Silicon Detector, CDF
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1 The CDF Silicon Detector in Run II

Coincident with the Tevatron Run II upgrade for higher $\sqrt{s}$ and increased luminosity, CDF replaced the Run I silicon detector with an entirely new detector with nearly double the coverage of both the luminous region and pseudo-rapidity (η), the ability to do three dimensional tracking, and enhanced impact parameter resolution for better B tagging [1,2]. The 8 layer, 704 ladder, 722432 channel detector that resulted is comprised of three subdetectors: SVXII, ISL, and L00 ("Layer Zero Zero"). SVXII is 360 double-sided ladders in a layout of six 15 cm axial sections $\times$ twelve 30° ϕ slices $\times$ five radial layers between 2.5 and 10.6 cm. ISL covers the area between SVXII and the CDF wire tracker (COT), with 296 double-sided ladders at radii of 20 or 28 cm, in total *1.9 m* long, providing silicon hits out to $|\eta| \leq 2$. L00 is a single-sided layer of 48 ladders mounted directly on the beampipe, 1.5 cm from the beamline, which enhances the impact parameter resolution. The $r-\phi$ and $r-z$ views of the detector are shown in Figure 1.

The three subdetectors share the same readout system, starting with the SVX3D chip, a custom designed ASIC with a 128 channel $\times$ 46 capacitor

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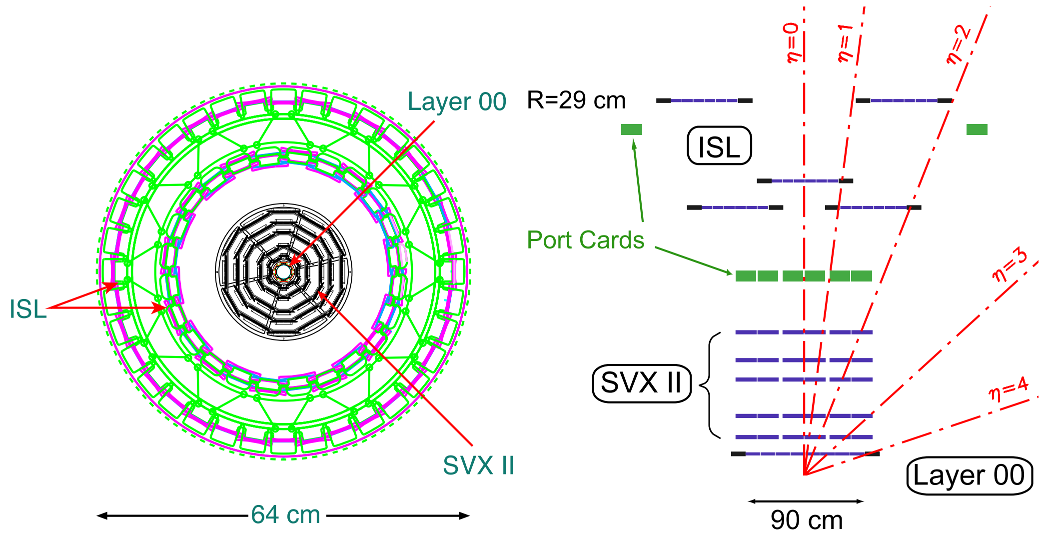

Fig. 1. $r-\phi$ and $r-z$ perspectives of the Silicon detector, showing all sub-components. Note the compression of the z scale.

analog storage ring, which makes it possible to acquire data in a "deadtime-less" fashion, integrating charge on one capacitor while reading out another. The SVX3D chip also features common mode noise suppression, sparsification, and other settings used to optimize the charge collection. A "wedge" of up to 5 ladders are serviced by one "portcard" mounted near the detector which provides a $1 \rightarrow 5$ fanout of electrical control signals and converts the data from electrical to optical for long distance transmission, as well as bringing in the analog, digital, and bias voltages to the chips and ladders. Behind this is a VME based data acquisition system which controls the entire detector and presents data to the Level 2 and Level 3 trigger systems. All detectors are incorporated in the same power distribution, cooling, interlock, and radiation protection systems.

2 Silicon Commissioning Experience

Commissioning commenced with the onset of Run II in early 2001. Since then, progress has been steady in getting the detector to a robust operating point, but seriously hampered by a series of problems, from which lessons for future detectors can be drawn. The first serious setback in commissioning was that the full detector was not outfitted with power supplies until late October, forcing "supply juggling" to ensure functionality and cabling during installation. Furthermore, the supply interlock mechanisms failed, such that the detector could be powered without cooling. This danger necessitated the shutdown of all Silicon operation until the problem was solved. The second set of problems arose from a lack of testing under realistic conditions. This manifested itself in a variety of ways, most notably the discovery of cooling lines blocked by epoxy in ISL, which have since been bored out with a laser, but also the presence of excess noise in L00 [3], and mismatches in optical power of receivers and transmitters [4], both of which required much effort to work around. The solutions were developed as soon as the issues were exposed by the true operating conditions, but could have been seen before.

In contrast, the last set of impediments were not observable before installation, as they are either *beam* or *magnetic field* induced damage. First, in coincidence with large beam dumps, damage occurred in the analog power distribution to single SVX3D chips on a ladder, as well as to the ladder and VME power supplies. The chip damage diagnosis shut down the detector for a month during bench studies to understand what was damaged, since the damaged parts are inaccessible, and the real cause of the loss of analog power is still unresolved, although more interlocks and monitoring of the beam conditions have mitigated the problem. Considerable delay may have been eliminated had the failure modes been well catagorized before installation.

More recently, high rate data acquisition has exposed a weakness in the digital power distribution to the the z-side chips. This weakness stems from a Lorentz force-induced resonance on wire bonds carrying the digital current from the ϕ side to the z side or a ladder. These "Jumper" bonds are perpendicular to the magnetic field, are not encapsulated, and carry current swings of $\sim$ 100 mA during readout of the ladder. At particular *fixed* readout rates, in a magnetic field of 1.4 T, the wire bonds oscillate, undergo fatigue, and eventually break. This effect is also still under study, not only to understand how to prevent it in CDF, but also for potential influence on other detectors [5].. In summary, having all pieces available, testing under operational conditions, and catagorizing in detail all failure modes are the important lessons to take away from the silicon commissioning experience.

3 Performance of the Silicon

Despite the litany of problems described in the previous section, by July 2002 over 90% of the silicon detector was powered, and more than 80% reading out quality data. For any ladder type and chip setting on average $\frac{Signal}{Noise} \geq 10$, with operating conditions set at 11-15 depending on ladder type. Figure 2 shows a distribution of a typical ladder's pedestal and signal ADC counts, exhibiting clear seperation between the gaussian noise and Landau distribution for the signal. With high signal to noise, the single hit efficiencies can be kept $\geq$ 99%, maintaining high signal efficiency without prohibitive data volume. With tracks in the data both the global and relative alignment continue to improve. In addition, the cluster resolution of the detector is as expected,

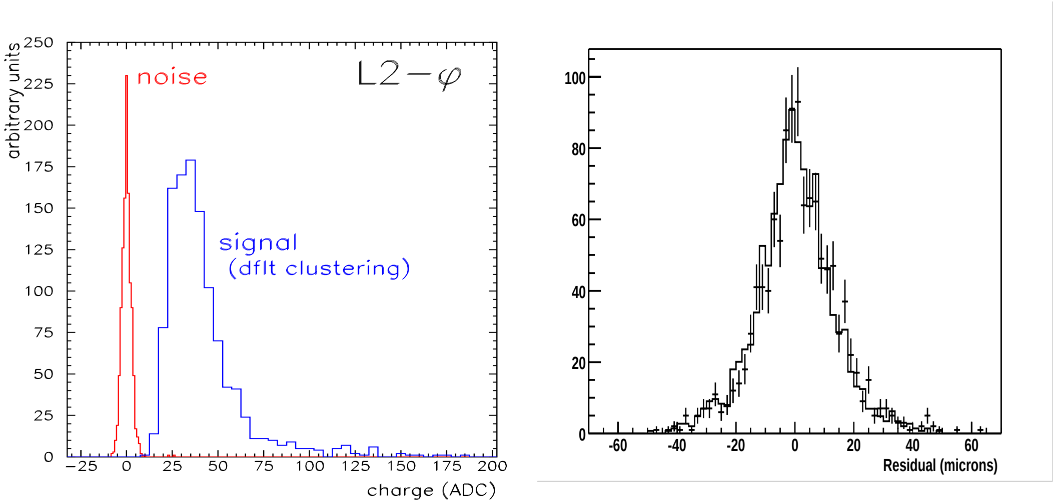

Fig. 2. Pedestal and signal for a SVXII L2 ϕ side ladder, and Two-Strip ϕ cluster resolution $\sim$ 9 μm (points), which agrees with the Monte Carlo simulation (histogram)

with for example an 9 μm intrinsic resolution on 2 strip clusters for the $r-\phi$ measurement, as shown in Figure 2. In general, the raw silicon detector performance shows promise for physics in Run II.

4 Tracking Applications

While performance benchmarks are necessary for validation, the real test of the detector is whether one can perform measurements. In addition to traditional offline tracking, the silicon detector is also utilized in the Level 2 trigger every $\sim$ 50 μs, where tracking information from the COT is combined with silicon hits and high impact parameter tracks are then used to trigger on heavy flavor physics. This allows CDF to trigger on lepton-less B decays, which both relieves the penalty of the small B leptonic branching fraction and enhances the fraction of fully reconstructed B decays in the data. The details and results of this application were presented to the conference and can be found in [6]. Of course, the detector is also used in full blown offline reconstruction and tracking, and preliminary results were presented to the summer conferences. Figure 4 shows two examples; a measurement of the inclusive B lifetime from B $\rightarrow$ JψX, and the B$^+$ mass from the fully hadronic decay B $\rightarrow$ Dπ $\rightarrow$ K$\pi\pi$. The conclusion is that this detector is useful for collecting and analyzing interesting physics data, and results from CDF II will be published soon.

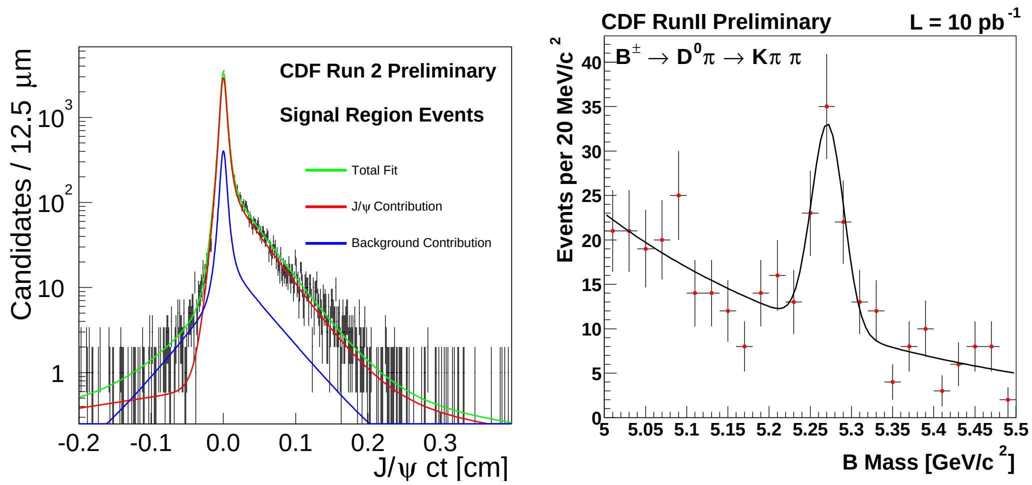

Fig. 3. Examples of preliminary results using the Silicon detector: Inclusive B lifetime from B $\rightarrow$ J/ψX [7], and fully reconstructed hadronic B decays: B $\rightarrow$ Dπ $\rightarrow$ K$\pi\pi$ [8]

5 Conclusion

With the first $\sim 35\ pb^{-1}$ of Run II data, the new CDF silicon detector has been commissioned, with some setbacks, and is currently taking data of a quality useful for competitive measurements. The detector will continue to improve as subtle problems are addressed, until the end of its useful lifetime, when the Run IIb detector will be installed [9].

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